Environmental Protection Agency

Heavy-Duty Diesel Engine Mapping Procedure

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NVFEL Reference Number

754C

Implementation Approval

Original Procedure Authorized by EPCN #127 on 05-20-93

Revision Description

(1) 11-20-95 The purpose of this change is to revise the procedure as described in EPCN #177.

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Attachments

1. Purpose

The purpose of this procedure is to generate a maximum torque curve for each engine from curb idle through the manufacturer's rated speed. The maximum torque curve is subsequently used to generate data for the transient test cycle for that specific engine.

2. Test Article Description

Diesel engines submitted for testing to the Environmental Protection Agency (EPA) Testing Services Division (TSD) Heavy-Duty Engine Testing (HDET). This procedure especially applies to engines defined as heavy-duty engines in the Code of Federal Regulations.

3. References

3.1 "Code of Federal Regulations," Vol. 40 Part 86, Subpart N, Sections 86.1332 and 86-1333

3.2 Environmental Protection Agency (EPA) current safety policies

4. Required Equipment

4.1 Form 751-01, "HDET - Engine and Test Specifications," (see TP 751)

Note: This form must be completed prior to starting Section 7 of this procedure.

4.2 Form 752-02, "HDET - Diesel Engine Startup" (see TP 752)

4.3 Form 754-01, "HDET - Diesel Engine Mapping" (Attachment A)

4.4 "Cellmate II Operations Manual"

4.5 Electric Engine Dynamometer

Equipment used: GE, Model 42 G 408 AD

4.6 Dynamometer Controller

Equipment used: Digalog, Model Cellmate II

4.7 Data Acquisition System

Equipment used: Digalog, Model Cellmate II

4.8 Throttle Controller

Equipment used: Digalog, Model Cellmate II

4.9 Throttle Amplifier

Equipment used: Digalog, Model TC

4.10 Throttle Actuator

Equipment used: Foxboro-Jordan, Model NC 10596

4.11 Test cell temperature monitoring system

Equipment used: Laboratory standard type “J” thermocouple (minimum 15 required) and the Digalog Cellmate II.

4.12 Dynamometer torque and speed display instruments

Equipment used: Daytronic Signal Conditioners:
Model 9178A, Strain Gage conditioner (2)
Model 9140, Frequency-to-voltage conditioner (2)
Model 9515A, Digital Indicator (4)

4.13 Barometer

Equipment used: Bell and Howell type CEC2500

4.14 CVS Compressor Unit (Blower)

Equipment used: Spencer Turbine Turbo Compressor, Model 2060 HMOD

5. Precautions

5.1 An operator must remain at the dynamometer console during engine operation so they can activate the “Emergency Stop” button if a potentially hazardous situation arises.

5.2 No personnel are allowed in the test cell while the engine is in operation, except to perform adjustments or tests which specifically require their presence at that time.

5.3 Any person entering the test cell during engine operation must wear hearing protection, safety glasses, and safety shoes. This person must stay out of line with rotating engine and drive shaft components as much as possible.

5.4 The engine must be checked for hydrostatic lock. Hydrostatic lock is a condition which results from an incompressible fluid collecting in a cylinder to the extent that its volume is greater than the total volume of the combustion chamber when the piston is at top dead center. If fluid exists in the chamber at this time, the piston may not be able to complete its upward stroke and serious damage to the engine can occur if the dynamometer is turning the engine.

Prior to starting the engine, the engine crankshaft is manually turned at least two revolutions prior to operation to ensure that conditions of hydrostatic lock do not exist. The direction of engine rotation is recorded on Form 751-01.

5.5 If the exhaust is connected to the CVS unit, the “EXHAUST SELECTION VALVE” must be set to the “CELL 2” position.

5.6 The engine oil level must be checked prior to every engine start, and if any is added the amount must be recorded on Form 752-01.

5.7 The dynamometer speed and engine throttle controls must be set to zero prior to activating the control panel.

6. Visual Inspections

Visual inspection of the engine and dynamometer setup is conducted prior to starting the engine. Instructions for specific inspections are covered in Section 7, Test Article Preparation.

7. Test Article Preparation

7.1 If Form 751-01 specifications require an engine break-in sequence, verify that the it has been performed. Ensure that all completed copies of Form 753-01 are included with the test packet for the engine.

7.2 At the beginning of each test day, perform the checks listed on Form 752-01.

If there are any interruptions in testing which may potentially alter any of the adjustments or settings checked, repeat the process.

7.3 Verify the speed, torque, and throttle position sensors are calibrated as described in the "Cellmate Operations Manual."

7.4 Verify that all the required thermocouples are connected and recording the proper values in the Cellmate II.

Note: Input boards in the Cellmate II have the capacity to accept 12 thermocouples. If all 12 slots are not filled, the voltage readings sent to the Cellmate II can be affected and can cause erroneous readings.

It is important to ensure that all the thermocouple slots have plugs in them, even if they are not used. The Cellmate II will only record data from the thermocouples it is programmed to read.

7.1 On Form 754-01, record the "Engine Identification" and "Test Number."

7.6 Prepare the Cellmate II for engine mapping. Perform the steps in "Mapping Section" of the "Cellmate II Operations Manual."

8. Test Procedure

100 Dynamometer Control Panel Preparation

101 Verify that Form 752-01 has been completed.

102 Apply power to the motor/generator (MG) by pressing the green "START" button above the "MG SET" label. The button will illuminate when the MG set is operating. Operating the MG set ensures that the dyno armature is floating on a film of oil.

103 Turn the dyno "POWER" switch to the "ON" position.

104 Turn the "FUEL / IGN." switch to the "ON" position.

105 Press the "RESET" button. A click should be heard, indicating solenoid operation, and the green light labeled "FUEL ON" will illuminate.

106 Apply power to the dynamometer by pushing the green DYNA "ON" button. The green button will illuminate, indicating that the dynamometer is ready for use.

107 Press the green “Auto” button. The button will illuminate, indicating that the dynamometer is in the auto mode.

Note: The Auto/Manual buttons allow for either manual operation or Cellmate II automatic control of the dynamometer. Pressing either button will set the dynamometer to the indicated mode.

108 Turn on the “THROTTLE CONTROLLER” by pressing the two yellow buttons located on the front panel. The two buttons will illuminate, indicating that the controller is on.

109 Turn the Cellmate II “AUTO/MANUAL” switch to the “MANUAL” position and turn the “CELL #1/CELL #2” switch to the “CELL #2” position.

200 Engine Operation

The symbols < > are used to indicate a key on either the Cellmate II Computer Control System or Macintosh computer keyboards.

Example: Press <Return>. This means that you need to press the key labeled “Return.”

201 Look up the maximum rated speed on Form 751-01 for this engine and enter this value into the Cellmate II “Manufacturers Specified Rated Speed.”

On Form 754-01, record this rpm on the “Manufacturers Specified Rated Speed” line.

202 On Form 754-01, record the “Barometric Pressure at Start” reading.

203 Press <Return> to start the engine. The Cellmate II will then automatically perform the 2-stage mapping. During the wide-open-throttle (WOT) at rated speed warm-up, set the inlet depression and exhaust back-pressure restrictors to the specifications on Form 751-01.

First stage: Engine warm-up

Idle for 2 to 3 minutes (no torque applied).

Peak torque speed (supplied by the manufacturer) and 50 percent power for 5 to 7 minutes.

One of the following, as selected in Step 203:

Normal Warm-up - WOT and rated speed for 30 minutes,

or

Stability Warm-up - WOT and rated speed until the engine oil and coolant temperatures are stable within 2 percent for 2 minutes.

Second stage: Maximum power curve

The Cellmate II will terminate the warm-up by returning the engine to idle and then proceed by increasing the speed up to the maximum rated speed rpm.

The engine speed will be increased by the dynamometer at a rate of 8 ±1 rpm per second starting from the engine curb idle speed.

The engine will be at full throttle for the duration of the mapping.

The Cellmate II will record the speed and torque data at a sample rate of 10 per second.

204 During the automatic mapping process the dynamometer operator will monitor the instrumentation, test cell, and engine for abnormal occurrences and take corrective action as necessary.

205 When the rpm reaches the maximum selected mapping speed, the Cellmate II will command the engine to an idle condition for a cooling down period.

The Cellmate II will display the idle speed. Compare this speed reading to the curb idle speed specification on Form 751-01 If it is outside the tolerance, record the Cellmate II idle speed on the comments line of Form 754-01.

The Cellmate II will stop the engine after the cool down period.

206 Turn the “POWER” switch on the dyno control panel to “OFF.”

207 Turn the “FUEL / IGN.” switch to “OFF.”

208 Press the MG red “STOP” button.

209 The Digalog will prompt the operator “Enter Y to use measured.” Refer to the “Cellmate II Operations Manual” for details.

210 Referring to the “Cellmate II Operations Manual” as needed, transfer the Cellmate II “HDT Map Report for EPA Certification” (Attachment B) and the “1RPM Map Report” (Attachment C) data to the Macintosh computer.

211 Using the “1RPM Map Report”:

Determine the maximum horsepower (HP) produced. On Form 754-01, record this value on the “Maximum HP” line.

Calculate 98 percent of the maximum HP value. On Form 754-01, record this value on the “98% of Maximum HP” line.

Locate the low and high engine speeds at which 98 percent power is observed. Use the lowest low speed and highest high speed if more than one point exists. On Form 754-01, record the lowest speed on the “Low Engine Speed at 98% of Maximum HP” line.

On Form 754-01, record the highest speed on the “High Engine Speed at 98% of Maximum HP” line.

Average the two speeds above to determine the measured rated speed. On Form 754-01, record the rpm on the “Calculated Rated Speed” line.

212 Using the formula on Form 754-01, calculate the maximum speed. On Form 754-01, record the rpm on the “Calculated Maximum Speed” line.

213 Determine engine speeds.

Ungoverned engines:

Identify the maximum mapping speed at which 97 percent of maximum horsepower occurs after peak horsepower from the “1RPM Map Report.”

On Form 754-01, record the rpm on the “Maximum mapping speed for ungoverned engines at 97% Maximum HP after peak” line. Use the highest speed point if more than one exists.

Governed engines:

On Form 754-01, record the rpm at which the torque becomes zero on the "Maximum mapping speed for governed engines where speed at WOT drops to zero after peak" line.

The maximum mapping speed is where the torque drops off to zero after peak horsepower.

214 On Form 754-01, record the "Barometric Pressure at End" reading.

215 Add the start of test barometric pressure reading to the end of test barometric pressure reading and divide this value by 2, this is the average barometric pressure reading.

On Form 754-01, record the "Average Barometric Pressure" reading.

216 On Form 754-01, record the "Maximum Mapping Speed." This information is obtained from the Cellmate II "HDT Map Report for EPA Certification."

217 Using the data recorded on Form 754-01, determine if the maximum mapping speed is greater than value (2) and value (3) or (2) and (4).

If it is, place a check mark on Form 754-01 "Yes" line. If it is not, place the check mark on the "No" line.

218 If all acceptance criteria are met, the map is valid. Place a check mark on Form 754-01 "Yes" line.

If any criteria are not met, place the check mark on the "No" line.

219 On the "Comments" line, record any unusual conditions observed during the test that may effect the test results.

220 Sign and date Form 754-01 in the spaces provided.

9. Data Input

9.1 The results of the engine setup and visual inspection are recorded on Form 752-01.

9.2 The engine rpm and torque measurements are recorded electronically by the Cellmate II.

9.3 All measured temperatures are recorded by the Cellmate II.

9.4 Engine speed, power, and barometric pressure data are recorded on Form 754-01.

10. Data Analysis

10.1 Form 754-01, the Cellmate II "HDT Map Report for EPA Certification," and the "1RPM Map Report" are reviewed for completeness, accuracy, and compliance with all acceptance criteria.

10.2 A technician will review the reports and forms to verify that the correct "Engine Identification" and "Test Number" were recorded and that the technician who performed the process has signed and dated the forms.

10.3 The individual that validates the data (performs Step 10.1) signs and dates Form 754-01.

11. Data Output

Form 754-01, the Cellmate II "HDT Map Report for EPA Certification," and the "1RPM Map Report" are placed in the test packet for the engine.

12. Acceptance Criteria

12.1 The ambient temperature must be within 68-86 °F at the time the engine is started.

12.2 The CVS dilution air temperature must not be below 68 °F.

12.3 The barometric pressure must not change by more than 1 inch of mercury from the start to the end of the map.

For example, if the start-of-test barometer reading was 29.00 inches of mercury, then the end of test reading must be within 28.00-30.00 inches of mercury in order for the MAP to be valid.

12.4 The calculated maximum speed must be greater than the maximum rated speed and the 97 percent maximum horsepower speed or the wide-open-throttle torque equals zero speed values from Form 754-01.

12.5 The map curb idle speed must be within the specified tolerances on Form 751-01.

12.6 The cold-start warm-up must consist of an idling mode for 2 to 3 minutes, a motoring mode at the peak torque speed and 50 percent power for 5 to 7 minutes, and one of the two operations listed below:

WOT and rated speed for 25 to 30 minutes,

or

WOT and rated speed until the engine oil and coolant temperatures are stable within 2 percent for 2 minutes.

12.7 The engine mapping speed must be increased at a rate of 8 ±1 rpm per second.

12.8 Engine speed and torque must be recorded at a rate of at least one reading per second.

12.9 The maximum safe speed, minimum safe speed, and maximum oil and coolant temperature must comply with the specifications on Form 751-01.

12.10 The air inlet temperature must be within 68-86 °F for the engines specified on Form 751-01 as having “temperature dependent emission controls.” Otherwise it must be above 68 °F.

13. Quality Provisions

13.1 The technician's signature must appear on all forms and test records, certifying that the data entries are correct and complete.

13.2 All reports and test records are validated by a technician who did not perform the test.

13.3 The rpm, torque, and power data from the “1RPM Map Report” are transferred to the Macintosh computer for permanent storage.

Attachment A

HDET - Diesel Engine Mapping

Engine Identification: _____ **Test Number:** _____

Map Number: _____

(1) _____ rpm Manufacturers Specified Rated Speed

_____ inHg Barometric Pressure at Start

Record the following data from the "1RPM Map Report":

_____ HP Maximum HP

_____ HP 98% of Maximum HP

_____ rpm Low Engine Speed at 98% of Maximum HP

_____ rpm High Engine Speed at 98% of Maximum HP

_____ rpm Calculated Rated Speed (the average of the low and high)

_____ rpm Enter Selected Rated Speed for transient test cycle generation

$$\text{Calculated Maximum Speed} = \text{Curb Idle} + \frac{113 * (\text{Selected Rated Speed} - \text{Curb Idle})}{100}$$

(2) _____ rpm Calculated Maximum Speed (using the formula above)

(3) _____ rpm Maximum mapping speed for ungoverned engines at 97% Maximum HP after peak.

(4) _____ rpm Maximum mapping speed for governed engines where speed at WOT drops to zero after peak.

_____ inHg Barometric Pressure at End

_____ inHg Average Barometric Pressure

_____ rpm Actual Maximum Mapping Speed (from Cellmate II HDT Map Report)

___ Yes ___ No Maximum speed greater than value (2) and (3) or (4)

___ Yes ___ No All acceptance criteria are met and the MAP is valid.

Comments: _____

I have performed the steps in accordance with the requirements of Test Procedure 754.

Signature: _____ Date: _____

I have validated the data in accordance with the requirements of Test Procedure 754.

Signature: _____ Date: _____

Attachment B

HDT MAP REPORT
FOR EPA CERTIFICATION
Results

Engine: RNAD01 Diesel Manual No Clutch Gov M-Choke
Min/Max Safe RPM: 450 2960 Curb: 665 Rated RPMs: 2600 Citt: 0.0

Dyno Site: 2 Operator ID: LAODCS Ramp Map
Barometer: 29.13 Curb Idle: 665 W.O.T. :1200.0 Pk Torque: 1677 Pk Power: 2465
Mfr's orig rated: 2600 Specified: 2600 Measured: 2446
Max Map Speed: 2851
Rated for cert: 2600
Remarks: MAP 2 NAVISTAR OFF THE SHELF REBUILD

Map run on: 03/23/93 at: 11:56:00.00

	RPM	TQ	PWR	
Curb idle:	665	240.9	30.5	
Peak torque:	1677	510.4	162.9	
Peak power:	2465	440.7	206.8	
Mfr's orig rated:	2600	409.8	202.8	
Specified rated:	2600	409.8	202.8	
Measured rated:	2446	441.1	205.4	
Max mapping speed:	2851	44.7	24.2	
Rated for certific:	2600	409.8	202.8	per 86.1333-84.g

Mapping run covered adequate speed range

Attachment C

1RPM Map Report

665	240.9	30.5
666	237.6	30.1
667	240.7	30.5
668	240.2	30.5
669	240.9	30.6
670	241.7	30.8
671	240.6	30.7
672	239.4	30.6
673	240.8	30.8
674	242.2	31.0
675	243.7	31.3
676	243.7	31.3
677	244.9	31.5
678	246.2	31.7
679	241.1	31.1
680	243.0	31.4
681	245.0	31.7
682	245.2	31.8
683	245.5	31.9
684	245.8	32.0
685	246.1	32.0
686	246.5	32.1
687	248.2	32.4
688	243.6	31.9
689	245.3	32.1
690	248.9	32.7
691	244.1	32.1
692	249.0	32.8
693	247.9	32.7
694	246.8	32.6
695	250.0	33.0
696	250.2	33.1
697	250.4	33.2
698	250.3	33.2
699	250.1	33.2
700	249.6	33.2
701	250.2	33.3
702	250.8	33.5
703	252.5	33.7
704	251.9	33.7
705	249.0	33.4
706	254.1	34.1
707	252.7	34.0
708	251.3	33.8
709	255.0	34.4
710	251.0	33.9